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(54) **WIDE VIEWING ANGLE LIQUID CRYSTAL DISPLAY PANEL**

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(30) **Foreign Application Priority Data**

Feb. 24, 2005 (TW) .... 94105580 A

(51) **Int. Cl.**
G02F 1/1333 (2006.01)

(52) **U.S. Cl.** **349/86**; 349/88; 349/130

(58) **Field of Classification Search** 349/88, 349/86, 130, 178, 117, 96, 93, 132
See application file for complete search history.

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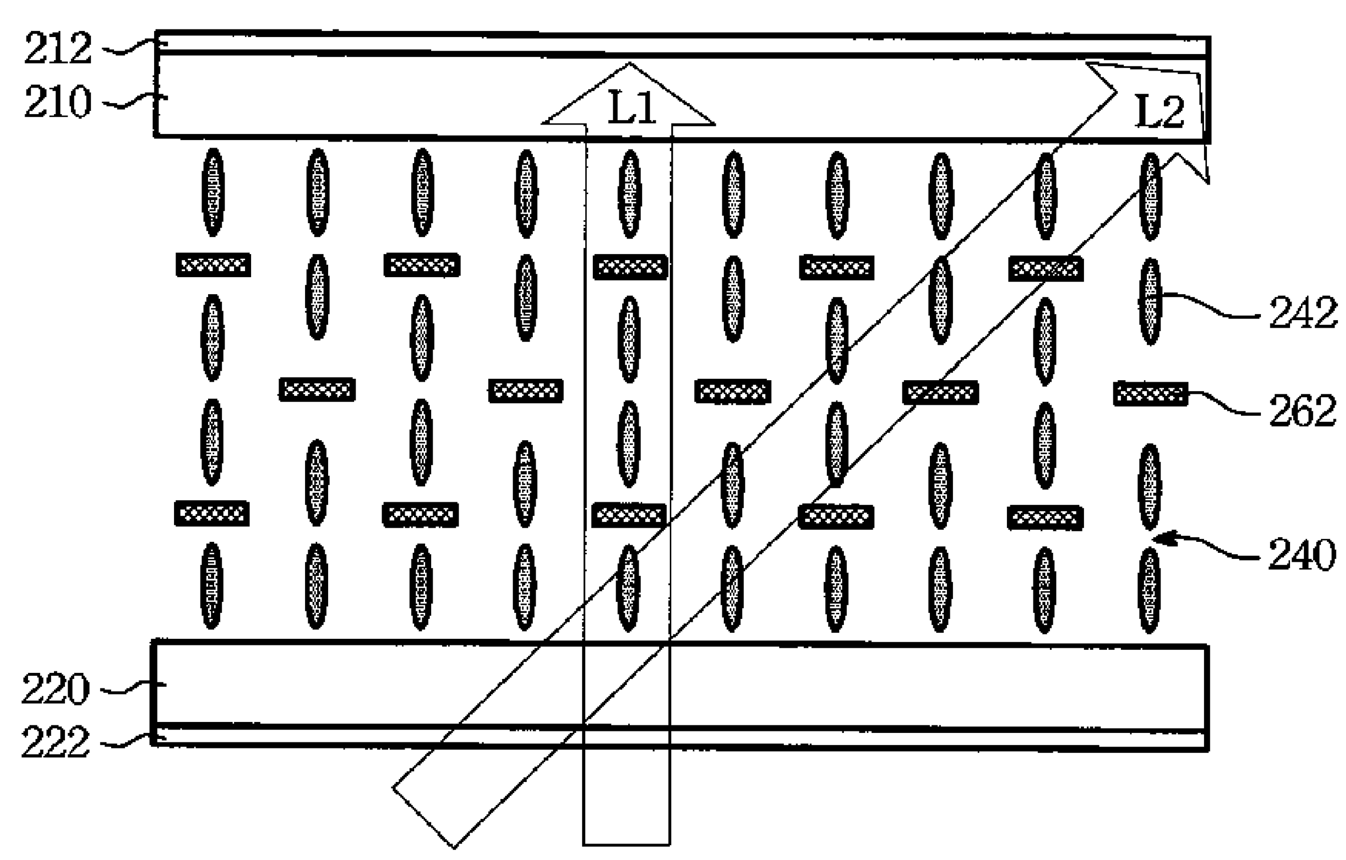
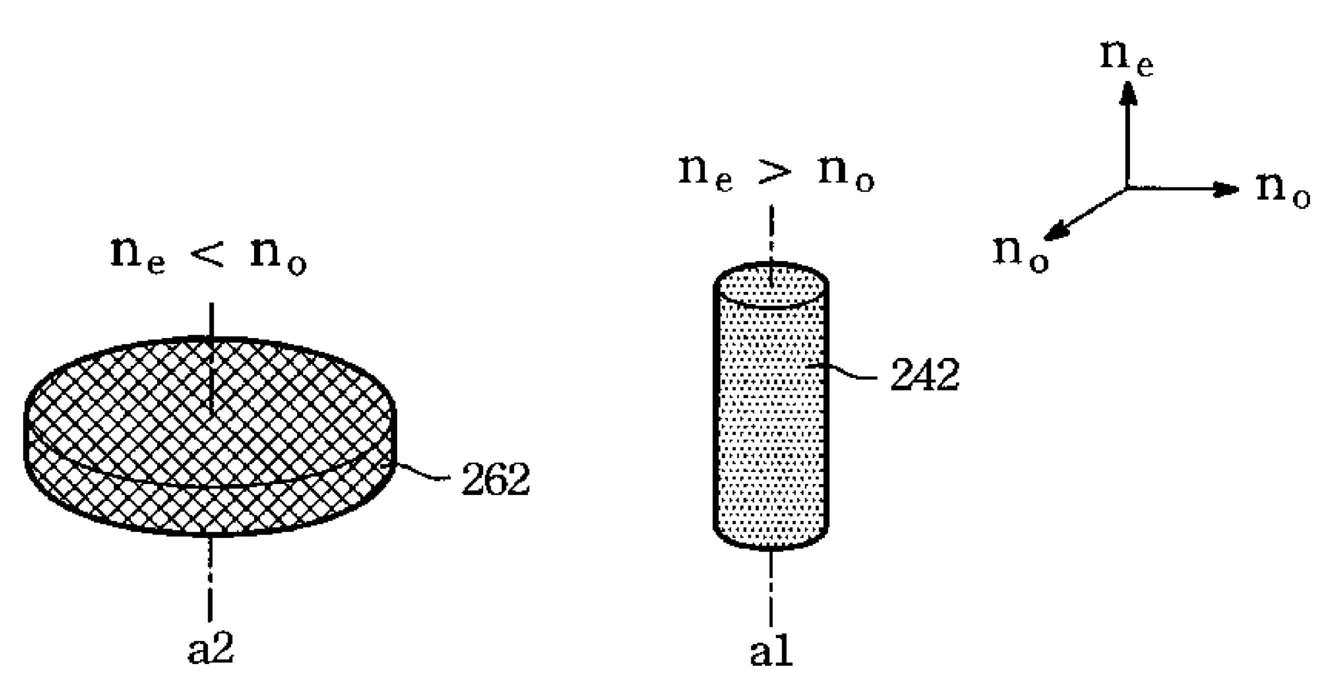
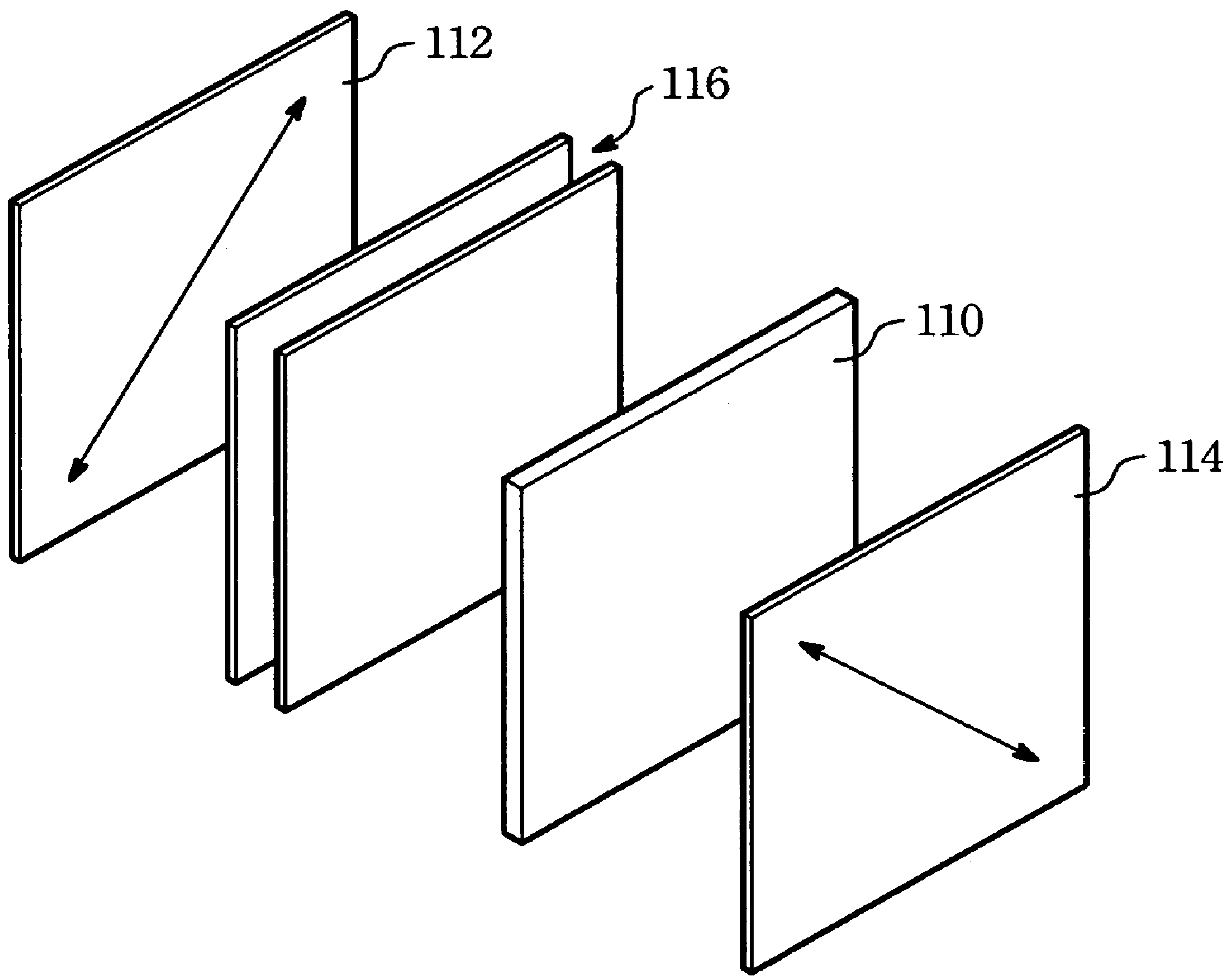
(57) **ABSTRACT**

A wide viewing angle liquid crystal display (LCD) panel comprising an upper substrate, a lower substrate, and a liquid crystal (LC) layer is provided. The upper substrate is assembled above the lower substrate. The LC layer is interposed between the two substrates. The LC layer has LC molecules mixed with a predetermined percentage of negative anisotropic monomers. The optical axes of the monomers and the LC molecules as the LCD panel in dark state forms an angle less than 10 degree.

19 Claims, 4 Drawing Sheets







F I G . 1
(Related Art)

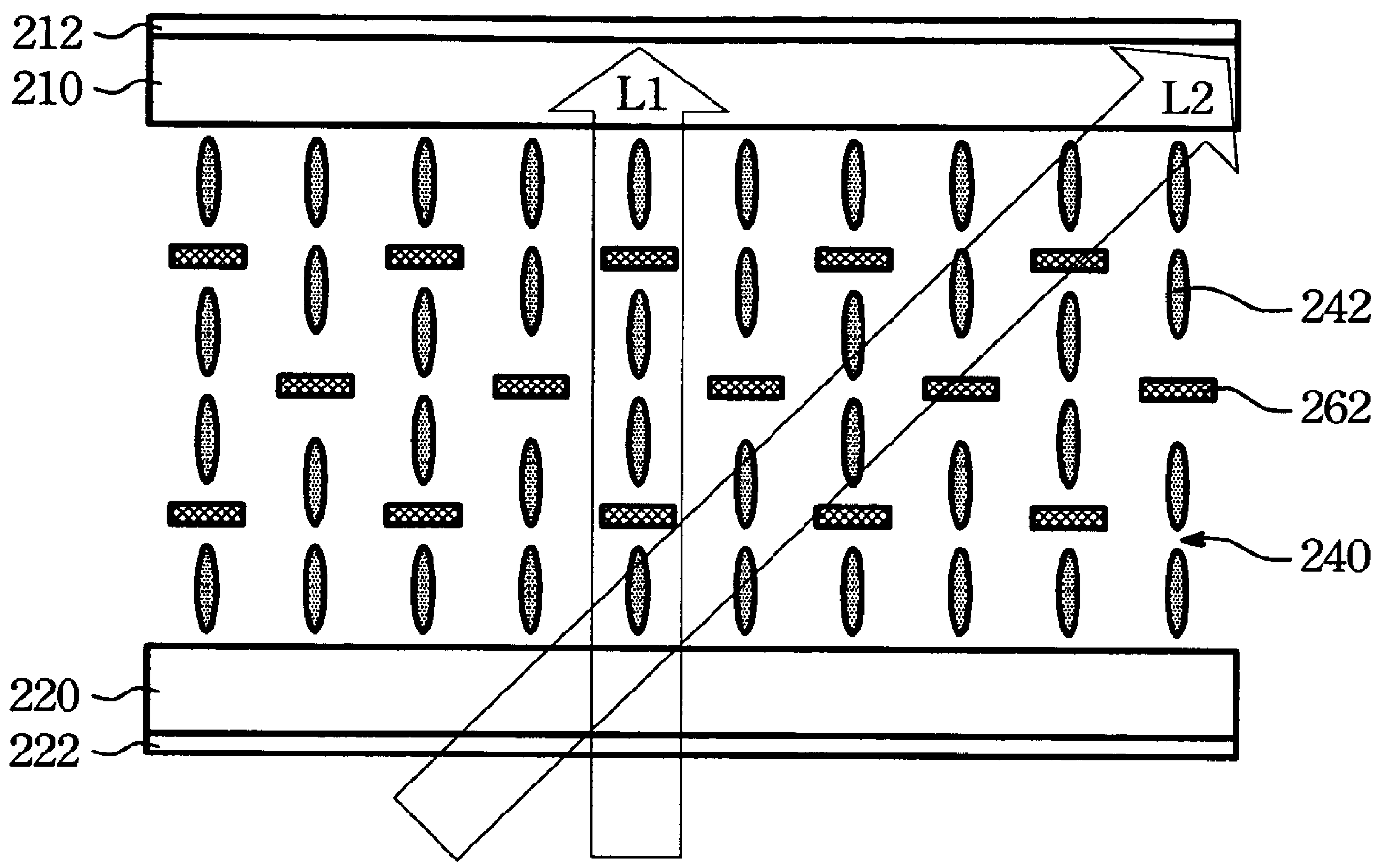


FIG. 2

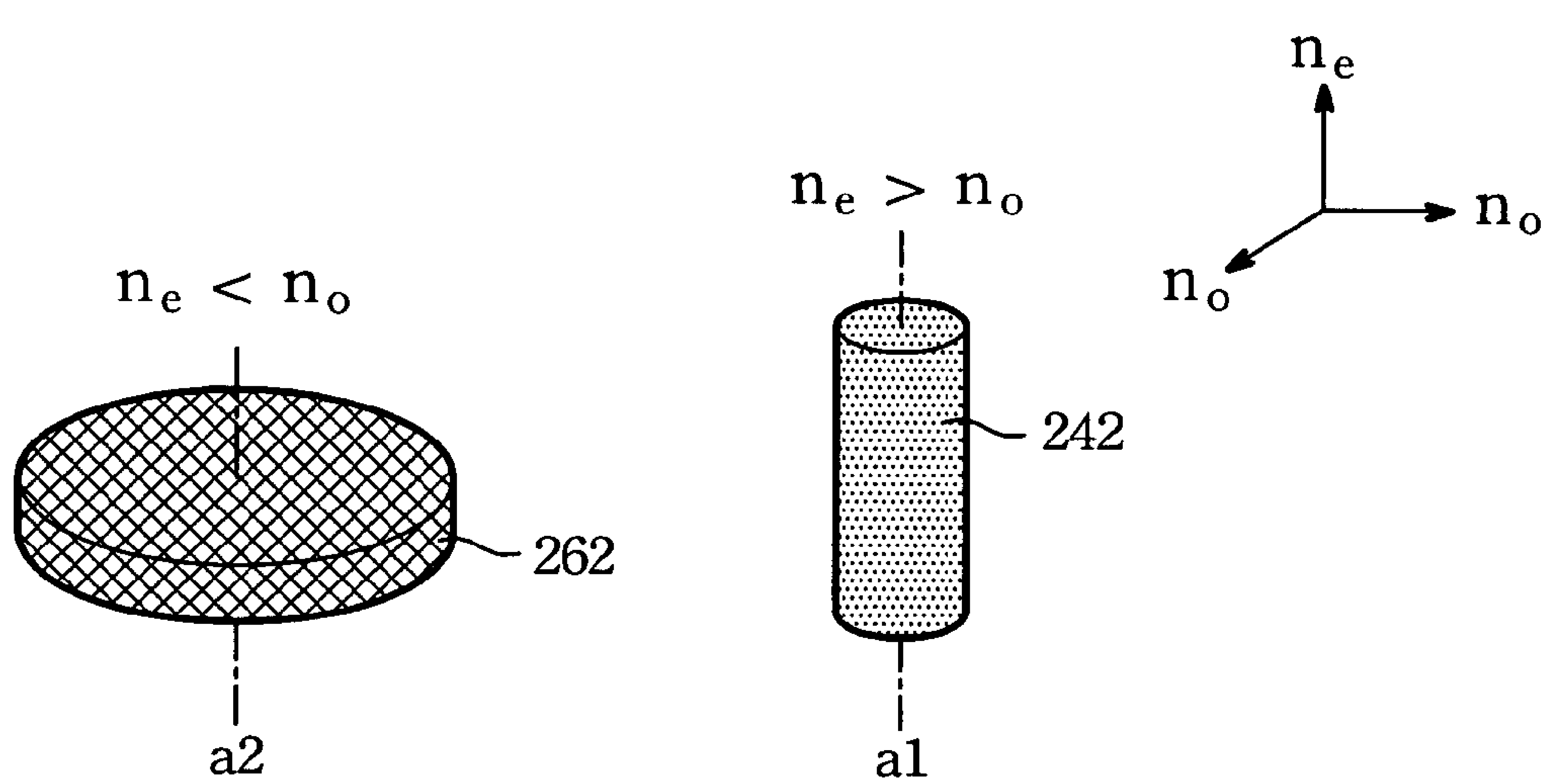


FIG. 2A

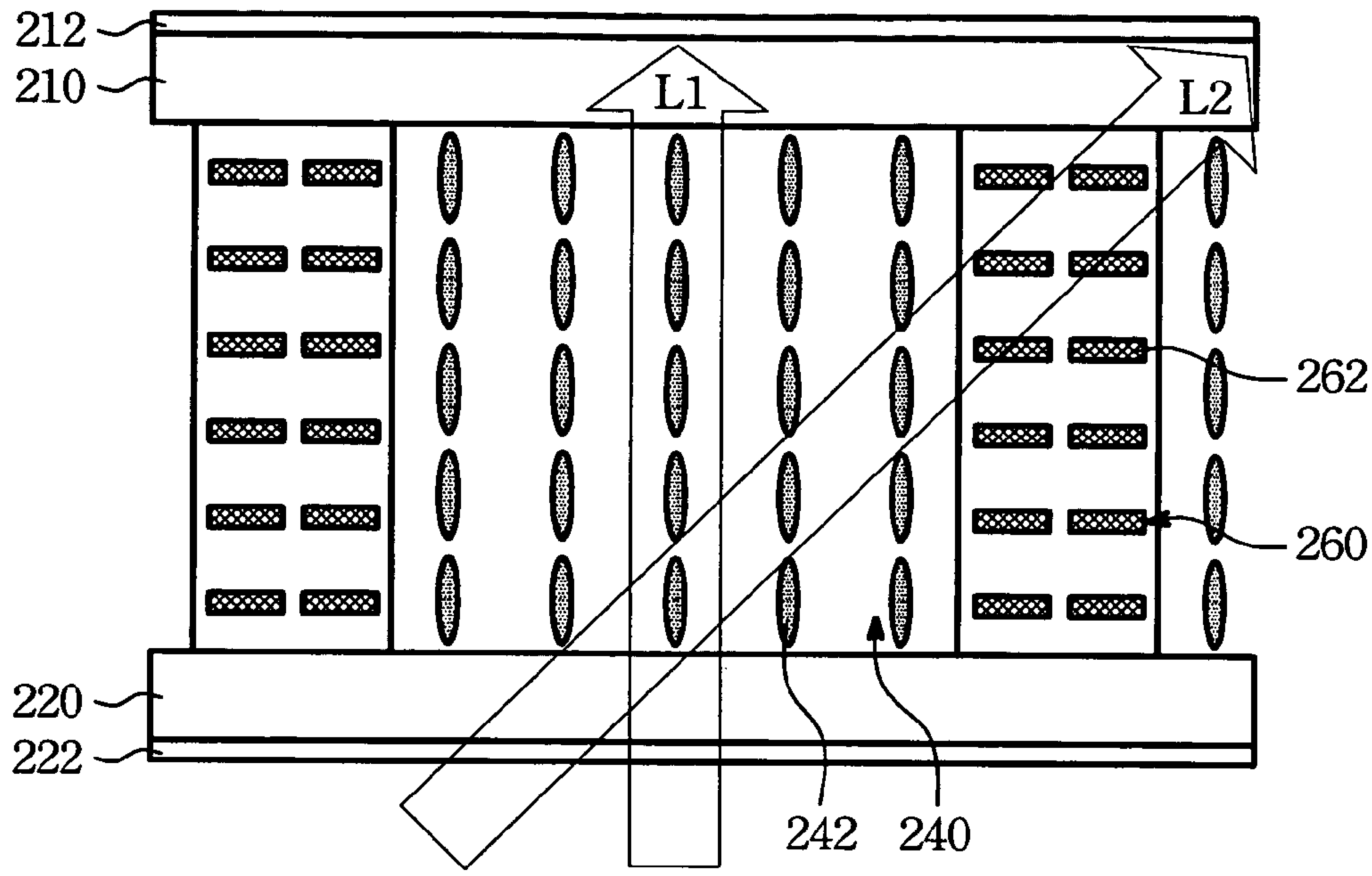

212
210
L1
L2
262
260
220
222
242
240

FIG.3

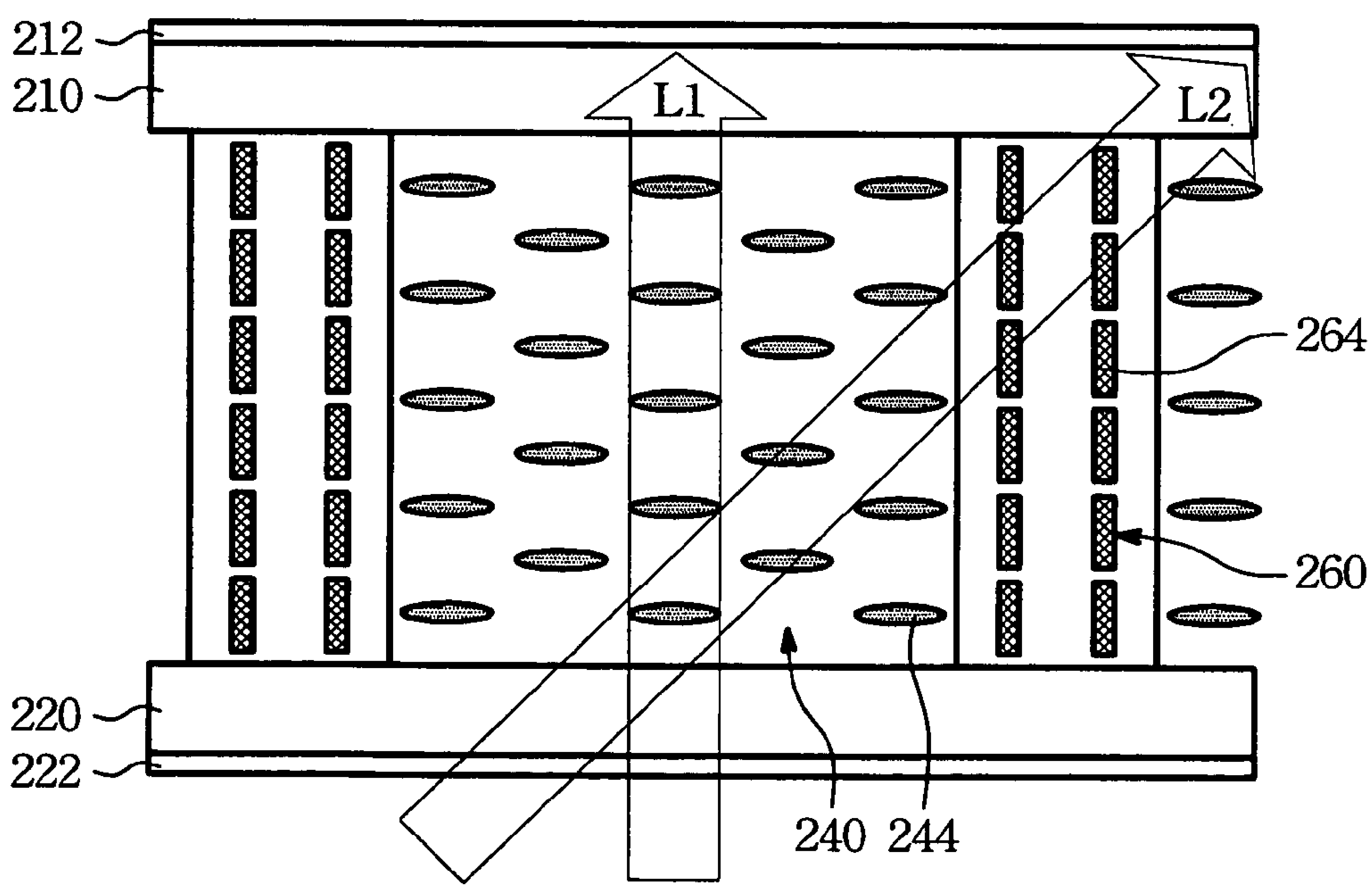

212
210
L1
L2
264
260
220
222
240
244

FIG.4

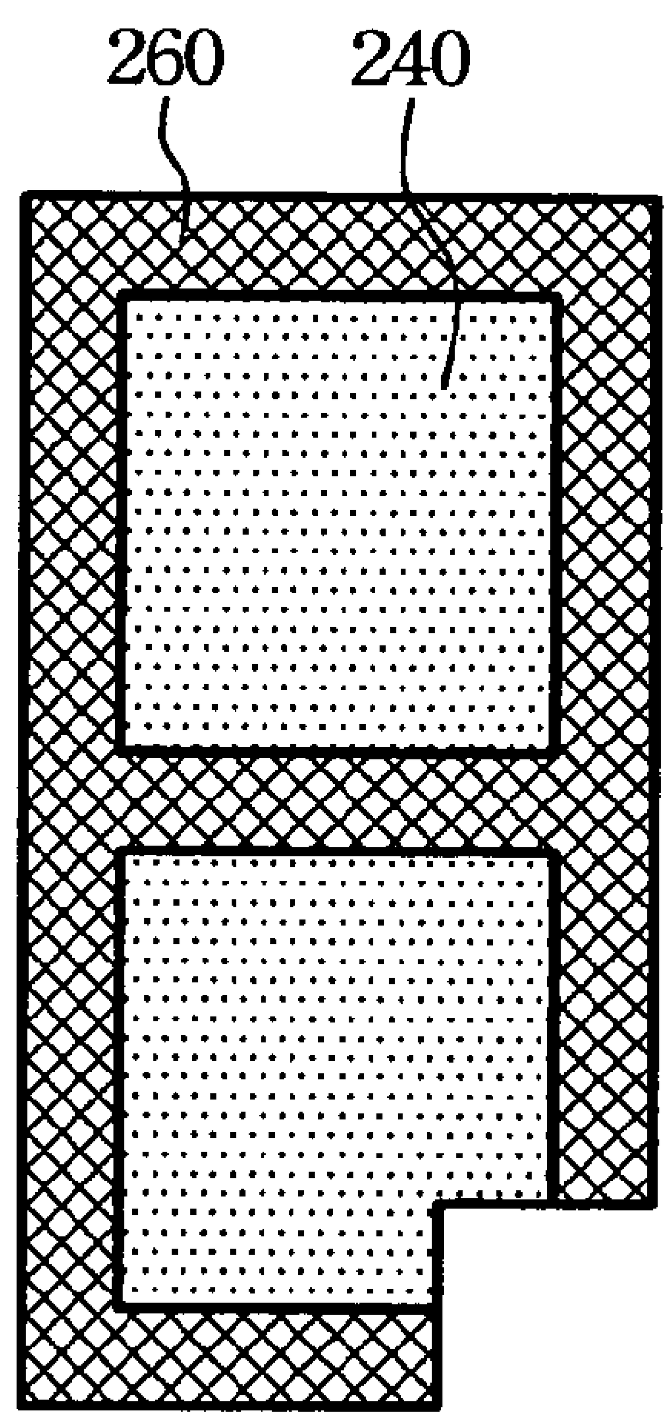


FIG.5

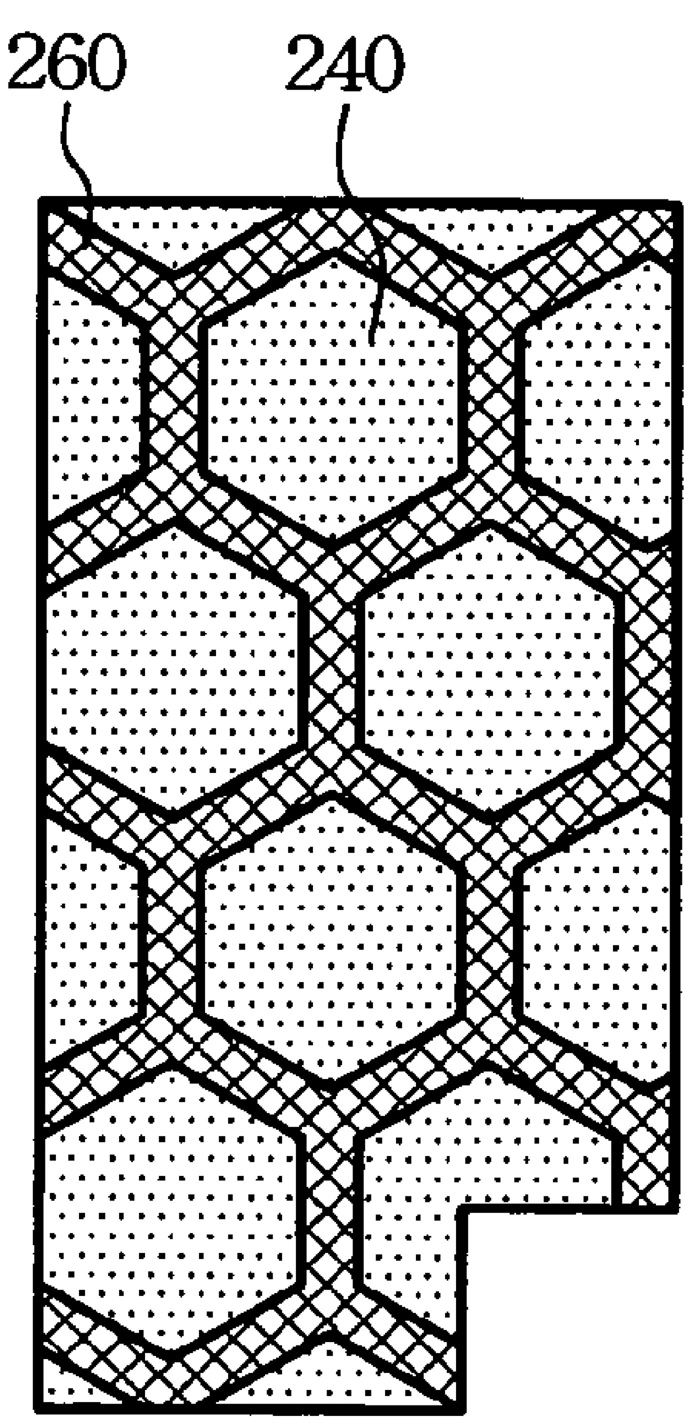


FIG.6

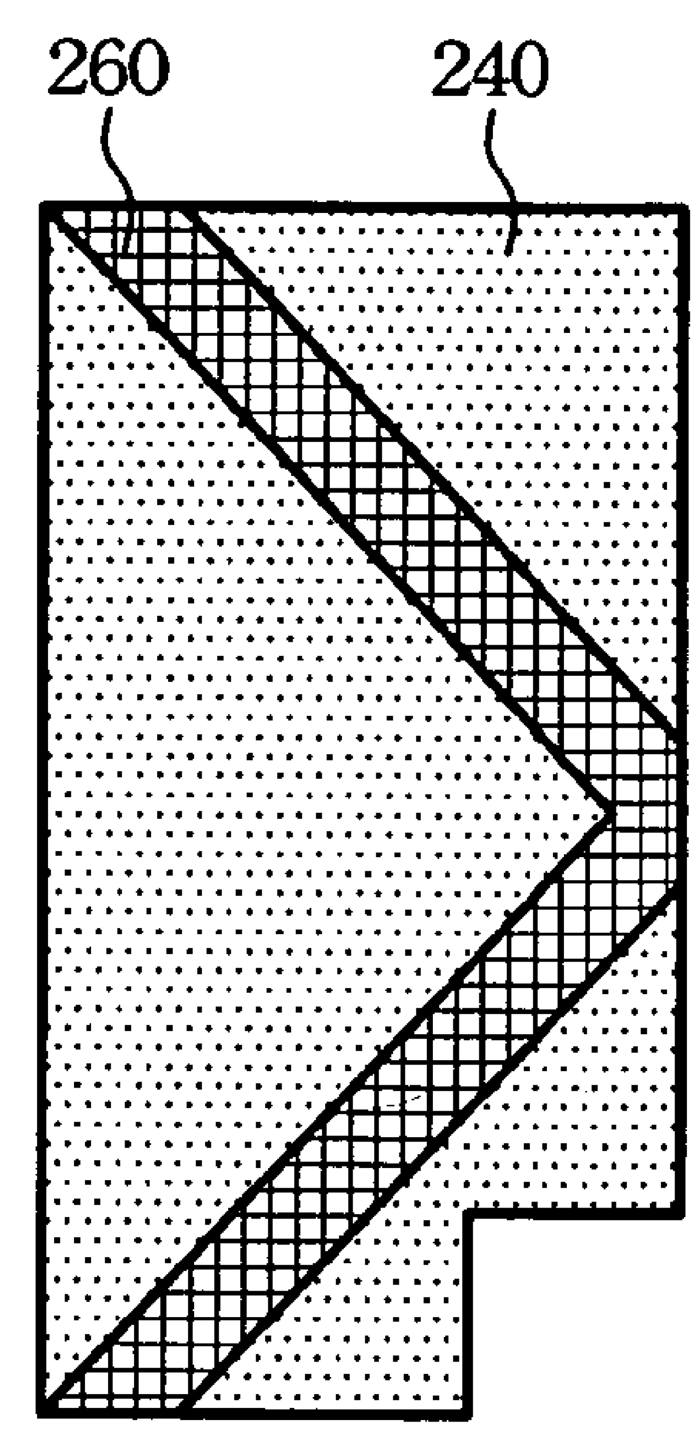


FIG.7

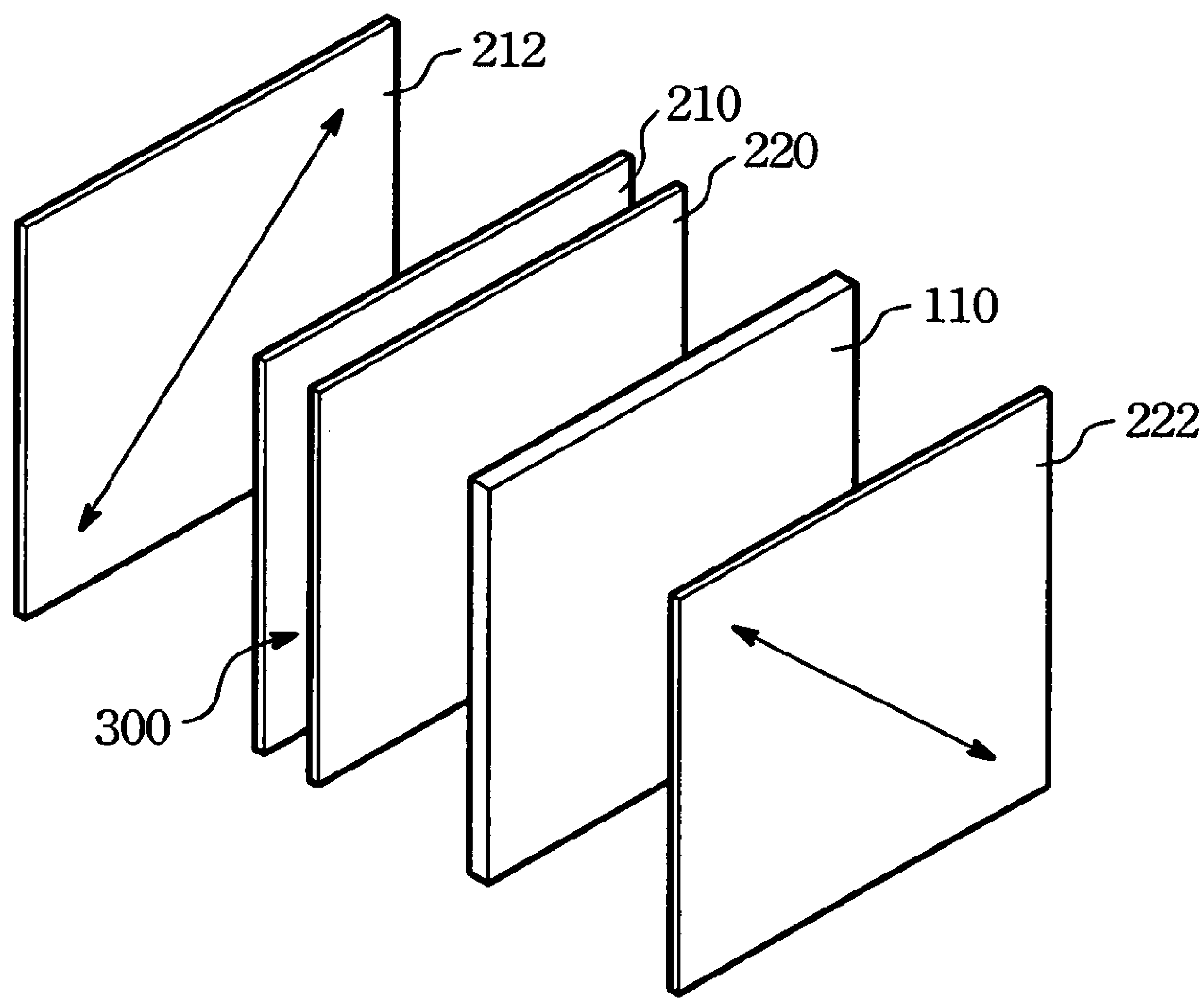


FIG.8

WIDE VIEWING ANGLE LIQUID CRYSTAL DISPLAY PANEL

This application claims the benefit of Taiwan application Serial No. 094105580, filed Feb. 24, 2005.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to a liquid crystal display (LCD) panel, and more particularly to a wide viewing angle LCD panel.

(2) Description of the Related Art

Attending with the improvement of thin film transistor (TFT) fabrication technology, LCD with the advantages of slim size, low power consumption, and low radiation emission, has become popular among various electronic devices, such as personal digital assistants (PDA), notebooks (NB), digital cameras (DC), digital videos (DV), cell phone, etc. However, the viewing angle of LCD at present is usually limited due to the optical behavior of liquid crystal (LC) layer with respect to light beams at various tilt angles.

Implementations for improving viewing angle of LCD are taught in some patents, see, e.g., American patent, U.S. Pat. No. 5,410,422, "GRAY SCALE LIQUID CRYSTAL DISPLAY HAVING A WIDE VIEWING ANGLE". FIG. **1** describes the method taught in the patent, to interpose a birefringence compensator **110** between two linear polarizers **112**,**114**. Light beam traveling through the LC layer **116** with a large tilt angle is usually engaged with phase retardation different from the light beam traveling normal to the LCD panel. The disclosed birefringence compensator **110** characterized with a negative phase retardation to compensate the phase retardation difference so as to increase viewing angle.

It is understood that the birefringence compensator **110** can be adapted to various LC molecule types, e.g., vertical aligned (VA) LC molecules, twisted nematic (TN) LC molecules, in-plane switch (IPS) LC molecules, etc. by properly compensating the phase retardation difference. However, the birefringence compensator **110** increases the thickness and the weight of the LCD panel, which leads to an important issue of increasing viewing angle without the benefit of birefringence compensator.

SUMMARY OF THE INVENTION

A wide viewing angle LCD panel comprising an upper substrate, a lower substrate, and an LC layer, is provided in the present invention. The lower substrate is disposed below the upper substrate. The LC layer is interposed between the two substrates. LC molecules within the LC layer are mixed with a predetermined proportion of anisotropic monomers. The angle between the directions of the optical axes of the anisotropic monomers and the LC molecules as the LCD panel in a dark state is less than 10 degree.

In an embodiment of the present invention, at least part of the monomers are polymerized to form a polymer network.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be specified with reference to its preferred embodiment illustrated in the drawings, in which:

FIG. **1** is a schematic view depicting a traditional LCD panel;

FIG. **2** is a cross section view depicting a first preferred embodiment of a wide viewing angle LCD panel in accordance with the present invention;

FIG. **2**A is a schematic view depicting a positive anisotropic LC molecule and a negative anisotropic monomer used in the present invention;

FIG. **3** is a cross section view depicting a second preferred embodiment of a wide viewing angle LCD panel in accordance with the present invention;

FIG. **4** is a cross section view depicting a third preferred embodiment of a wide viewing angle LCD panel in accordance with the present invention;

FIG. **5** is a top view depicting a first preferred embodiment of the layout of polymer network in a pixel device of the wide viewing angle LCD panel in accordance with the present invention;

FIG. **6** is a top view depicting a second preferred embodiment of the layout of polymer network in a pixel device of the wide viewing angle LCD panel in accordance with the present invention;

FIG. **7** is a top view depicting a third preferred embodiment of the layout of polymer network in a pixel device of the wide viewing angle LCD panel in accordance with the present invention; and

FIG. **8** is a schematic view depicting a fourth preferred embodiment of a wide viewing angle LCD panel in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As described in the related art of FIG. **1**, the birefringence compensator **110** shows an opposite retardation characteristic with respect to the LC layer **116**, so as to compensate the phase retardation deviation for light beams with large tilt angles. By compensating the retardation deviation, the light leakage event can be prevented and the viewing angle can be increased.

FIG. **2** shows a first preferred embodiment of a wide viewing angle LCD panel in accordance with the present invention. The LCD panel has an upper substrate **210**, a lower substrate **220**, and an LC layer **240**. The lower substrate **220** is disposed below the upper substrate **210**. A lower polarizer **222** is formed on a lower surface of the lower substrate **220**. An upper polarizer **212** is formed on an upper surface of the upper substrate **210**.

The LC layer **240** is interposed between the upper substrate **210** and the lower substrate **220**, and it is composed of LC molecules **242** mixed with a predetermined proportion of optical anisotropic monomers **262** uniformly distributed in the LC layer **240**. The LC molecules **242** are vertical aligned (VA) negative-type LC molecules. It is understood that the negative type LC molecules **242** has a tendency to change their optical axes a**1** in a direction perpendicular to the applied electrical field. In addition, as shown, when the LCD panel is in a dark state, the angle between the directions of the optical axes a**1**,a**2** of the monomers **262** and the LC molecules **242** respectively is less than 10 degree, or even pointing toward the same direction.

Referring to FIG. **2**A, in the LCD panel of the present embodiment, the LC molecules **242** are positive optical anisotropic (the ordinary refractive rate n_o greater than the extraordinary refractive rate n_e) and the monomers are negative optical anisotropic (n_o less than n_e). In contrast, as the LC molecules of negative optical anisotropic (n_o less than n_e) are adapted in the present embodiment, only the monomers of positive optical anisotropic (n_o greater than n_e) can be used.

As described above, as the LCD panel is in the dark state, the optical axes of the negative-type LC molecules **242** biases toward the direction perpendicular to the applied electric field, which is parallel to the upper substrate **210** or the lower substrate **220**. For a light beam L**1** traveling normal to the LCD panel, the LC molecules **242** and the monomers **262** have the optical axes in directions substantially the same as the light beam L**1**. Thus, the light beam L**1** shows no retardation after passing through the LC layer **240**. Since the upper polarizer **212** has an absorption axis perpendicular to that of the lower polarizer **222**, the light beam L**1** passing through the lower polarizer **222**, the lower substrate **220**, the LC layer **240** (including the LC molecules **242** and the monomers **262**), and the upper substrate **210** in a serial, but totally shielded by the upper polarizer **212**.

For a light beam L**2** traveling with a tilt angle, the optical axes of the LC molecules **242** and the monomers **262** are in directions different from the light beam L**2**. Thus, the light beam L**2** must be engaged with some phase retardation from the LC molecules **242** and the monomers **262** respectively after passing through the LC layer **240**. As described above, the LC molecules **242** and the monomers **262** are positive and negative optical anisotropic, respectively. The light beam L**2** accesses opposite retardation events from the molecules **242** and the monomers **262**. Thus, the unwanted retardation deviation from the LC molecules **242** can be compensated by the monomers **262** to prevent the light beam L**2** passing through the upper polarizer **212** from light leakage.

FIG. **3** shows a second preferred embodiment of a wide viewing angle LCD panel in accordance with the present invention. The LCD panel has an upper substrate **210**, a lower substrate **220**, an LC layer **240**, and a polymer network **260**. The lower substrate **220** is disposed under the upper substrate **210**. A lower polarizer **222** is formed on a lower surface of the lower substrate **220**. A upper polarizer **212** is formed on an upper surface of the upper substrate **210**. The LC layer **240** is interposed between the two substrates **210** and **220**.

In the present embodiment, the LC molecules **242** within the LC layer **240** are VA negative-type LC molecules. The polymer network **260** is composed of polymerized optical anisotropic monomers **262** and shows a wall-like structure extended from an upper surface of the lower substrate **220** toward the upper substrate **210**. There may be a gap formed between the polymer network **260** and the upper substrate **210**. The polymerization of the polymer network **260** restricts the orientation of the monomers **262** to guarantee the angle between the optical axes of the monomers **262** and the LC molecules **242** in the dark state less than 10 degree.

Referring to FIG. **3**, in the LCD panel of the present embodiment, the LC molecules **242** are positive optical anisotropic (n_o is greater than n_e) and the monomers are negative optical anisotropic (n_o is less than n_e). As shown, when the LCD panel is in the dark state, the optical axes of the LC molecules **242** within the LC layer **240** are in directions perpendicular to the upper substrate **210** or the lower substrate **220**. Thus, it is understood that the optical axes of the monomers **262** are also substantially perpendicular to the upper substrate **210** or the lower substrate **220**. For the light beam L**1** traveling normal to the LCD panel, the optical axes of the LC molecules **242** and the monomers **262** are substantially in directions the same as the light beam L**1**. Thus, the light beam L**1** shows no retardation after passing through the LC layer **240** and the polymer network **260**. Since the upper polarizer **212** has the absorption axis perpendicular to that of the lower polarizer **222**, the light beam L**1** passing through the lower polarizer **222** would be totally shielded by the upper polarizer **212**.

For the light beam L**2** traveling with a tilt angle, the optical axes of the LC molecules **242** and the monomers **262** are in directions different from the light beam L**2**. Thus, the light beam L**2** must be engaged with some phase retardation from the LC molecules **242** and the monomers **262** in the polymer network **260**, respectively, after passing through the LC layer **240**. As described above, the LC molecules **242** are positive optical anisotropic. The monomers **262** of negative optical anisotropic are polymerized to maintain in directions perpendicular to the upper substrate **210** or the lower substrate **220**. The light beam L**2** accesses opposite retardation events from the LC molecules **242** and the monomers **262** respectively. Thus, the unwanted retardation deviation of the LC molecules **242** is compensated by the monomers **262** to prevent the light beam L**2** passing through the upper polarizer **212** from light leakage.

In order to make sure the light beam L**2** accessing enough opposite phase retardation from the monomers **262**, the wall-like structure of the polymer network **260** may be extended from the upper surface of the lower substrate **220** toward the upper substrate **210**, or the wall-like structure of the polymer network **260** should be at least extend from the lower substrate **220** upward or from the upper substrate **210** downward with a gap formed between the upper substrate **210** or the lower substrate **220** and the polymer network **260** smaller than half the thickness of the LC layer **240**.

FIG. **4** shows a third preferred embodiment of the wide viewing angle LCD panel in accordance with the present invention. In contrast with the first embodiment of FIG. **2**, the present embodiment uses horizontal aligned LC molecules, such as in-plane switch (IPS) LC molecules, instead. It should be noted that the optical axes of the monomers **264** within the polymer network **260** are parallel to the upper substrate **210** or the lower substrate **220**, and an angle formed between the axes of the LC molecules **244** and the monomers **264** is less than 10 degree. For IPS LC molecules, the optical axes of the monomers **264** are substantially parallel to the upper substrate **210** or the lower substrate **220** where the monomers **264** are negative optical anisotropic. The optical axes of the monomers **264** are substantially perpendicular to the upper substrate **210** or the lower **220** substrate, or substantially parallel to the upper substrate **210** or the lower substrate **220** but perpendicular to the optical axes of LC molecules **244** where the monomers **264** are positive optical anisotropic.

As the LCD panel is in the dark state, the optical axes of the LC molecules **244** in the LC layer **240** are parallel to the upper substrate **210** or the lower substrate **220** and perpendicular to the absorption axis of the lower polarizer **222**. Since the light beam L**1** shows linearly polarization in a direction perpendicular to absorption axis of the lower polarizer **222** entering the LC layer **240**, the polarization direction of the light beam L**1** and the optical axes of the LC molecules **244** are substantially pointing to the same direction. In addition, the optical axes of the monomers **264** and the LC molecules **244** are substantially pointing to the same direction. Thus, the light beam L**1** accesses no retardation from the LC molecules **244** and the monomers **264**. Since the absorption axis of the upper polarizer **212** is perpendicular to that of the lower polarizer **222**, the light beam L**1** passing through the lower polarizer **222** would be totally shielded by the upper polarizer **212**.

For the light beam L**2** traveling with a tilt angle, there are angles formed between the linearly polarization direction of the light beam L**2** and the optical axes of the LC molecules **244** and the monomers **264**, respectively. Thus, the light beam

L2 must access retardation events from the LC molecules **244** and the monomers **264** within the polymer network **260** after passing through the LC layer **240**. As described above, since the LC molecules **244** and the monomers **264** are positive and negative optical anisotropic respectively, the light beam L2 must access opposite retardation from the LC molecules **244** and the monomers **264**. The unwanted retardation deviation from the LC molecules **244** can be compensated by the contribution of the monomers **264** so as to prevent the light beam L2 passing through the upper polarizer **212** from light leakage.

Although the above mentioned embodiments only describes the cases with VA type LC molecules **242** and IPS type LC molecules **244**, typical twisted nematic (TN) type LC molecules can be applied in the present invention, just under the limitation that the angle between the optical axes of the anisotropic monomers and TN type LC molecules as the LCD panel in the dark state less than 10 degree.

FIG. **5** shows a top view of a first preferred embodiment of the polymer network layout within a pixel device in accordance with the present invention. As shown, the polymer network **260** is a quadrilateral network distributed in the LC layer **240** to make sure the light beams with large tilt angles traveling along various directions may access opposite phase retardation from the LC molecules and the monomers in the polymer network **260**.

FIG. **6** shows a top view of a second preferred embodiment of the polymer network layout within a pixel device in accordance with the present invention. As shown, the polymer network **260** is a hexagonal network **260** distributed in the LC layer **240** to make sure that the light beams with large tilt angles traveling along various directions may access opposite phase retardation from the LC molecules and the monomers in the polymer network **260**.

FIG. **7** shows a top view of a third preferred embodiment of the polymer network layout within a pixel device in accordance with the present invention. As shown, the polymer network in the pixel device has two parts extended from a middle of an edge to both ends of an opposite edge to make sure that the light beams with large tilt angles traveling along various directions access opposite retardation from the LC molecules and the monomers in the polymer network **260**.

As mentioned above, the polymer network **260** adapted in the present invention restricts the orientation of the monomers **262**, **264** so as to achieve the object of compensating the retardation deviations of light beam L2 passing through the LC molecules **242**, **244** to increase the viewing angle of the LCD panel. Therefore, the compensator **110** described in related art can be omitted to reduce the fabrication cost, the weight, and the thickness of the LCD panel. In addition, for a concern of better compensation ability, in the fourth preferred embodiment of the LCD panel in accordance with the present invention as shown in FIG. **8**, the compensator **110**, such as an a-plate or a biaxial film, may be interposed between the lower substrate **220** and the lower polarizer **222** or the upper substrate **210** and the upper polarizer **212** (not shown) to further prevent the light leakage event of the LCD panel in the dark state.

While the embodiments of the present invention have been set forth for the purpose of disclosure, modifications of the disclosed embodiments of the present invention as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the spirit and scope of the present invention.

We claim:

1. A wide viewing angle liquid crystal display (LCD) panel comprising:

an upper substrate;

a lower substrate disposed below the upper substrate; and

a liquid crystal (LC) layer, interposed between the upper substrate and the lower substrate, having LC molecules mixed with a predetermined proportion of anisotropic monomers;

wherein an angle between optical axes of the an anisotropic monomers and the LC molecules is less than 10 degree as the wide viewing angle LCD panel is in a dark state and wherein the LC molecules are positive optical anisotropic while the monomers are negative optical anisotropic, and the LC molecules are negative optical anisotropic while the monomers are positive optical anisotropic.

2. The wide viewing angle LCD panel of claim **1**, wherein the monomers are uniformly distributed in the LC layer.

3. The wide viewing angle LCD panel of claim **1**, wherein the optical axes of the monomers and the LC molecules within the LC layer are substantially pointing toward the same direction as the LCD panel in the dark state.

4. The wide viewing angle LCD panel of claim **1**, wherein the LC molecules are vertical aligned (VA) LC molecules.

5. The wide viewing angle LCD panel of claim **4**, wherein the monomers are negative optical an isotropic, and the optical axes of the monomers are substantially perpendicular to the upper substrate or the lower substrate.

6. The wide viewing angle LCD panel of claim **4**, wherein the monomers are positive optical an isotropic characteristic, and the optical axes of the monomers are substantially parallel to the upper substrate or the lower substrate.

7. The wide viewing angle LCD panel of claim **1**, wherein the LC molecules are twisted nematic (TN) LC molecules.

8. The wide viewing angle LCD panel of claim **7**, wherein the monomers are negative optical an isotropic characteristic, and the optical axes of the monomers are substantially perpendicular to the upper substrate or the lower substrate.

9. The wide viewing angle LCD panel of claim **7**, wherein the monomers are positive optical an isotropic, and the optical axes of the monomers are substantially parallel to the upper substrate or the lower substrate.

10. The wide viewing angle LCD panel of claim **1**, wherein the LC molecules are in-plane switch (IPS) LC molecules.

11. The wide viewing angle LCD panel of claim **10**, wherein the monomers are negative optical an isotropic, and the optical axes of the monomers are substantially parallel to the upper substrate or the lower substrate.

12. The wide viewing angle LCD panel of claim **10**, wherein the monomers are positive optical an isotropic, and the optical axes of the monomers are substantially perpendicular to the upper substrate or the lower substrate.

13. The wide viewing angle LCD panel of claim **1**, wherein at least part of the monomers are polymerized to form a polymer network.

14. The wide viewing angle LCD panel of claim **13**, wherein the polymer network is a wall-like structure extending from the lower substrate toward the upper substrate with a gap formed between the polymer network and the upper substrate.

15. The wide viewing angle LCD panel of claim **13**, wherein the polymer network is a wall-like structure extended from the lower substrate toward the upper substrate.

16. The wide viewing angle LCD panel of claim **14**, wherein the gap is greater than half the thickness of the LC layer.

17. The wide viewing angle LCD panel of claim **1**, further comprising an upper polarizer disposed over the upper substrate, and a lower polarizer disposed below the lower substrate, wherein the absorption axes of the upper polarizer and the lower polarizer are substantially perpendicular with each other.

18. The wide viewing angle LCD panel of claim **17**, further comprising a compensator interposed between the upper polarizer and the upper substrate.

19. The wide viewing angle LCD panel of claim **17**, further comprising a compensator interposed between the lower polarizer and the lower substrate.

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